그린 컴퓨팅과 저전력 시스템

김 지 홍 Jihong Kim

Computer Architecture & Embedded Systems Laboratory
School of Computer Science & Engineering
Seoul National University

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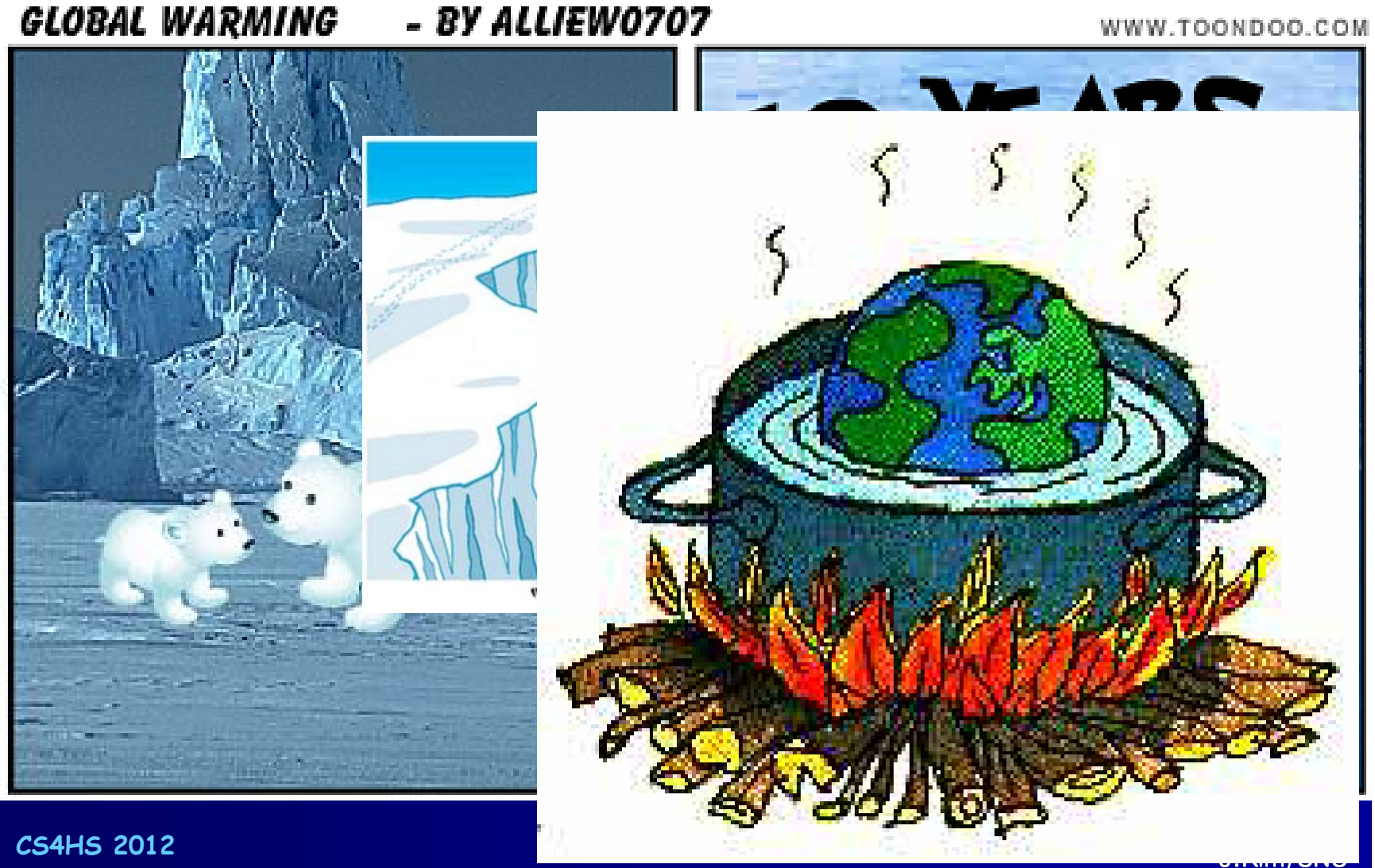
Outline

- Introduction to Global Warming
- Overview of Green Computing
- Overview of Low-Power Computing

지구온난화



전지구적인 문제: 지구온난화

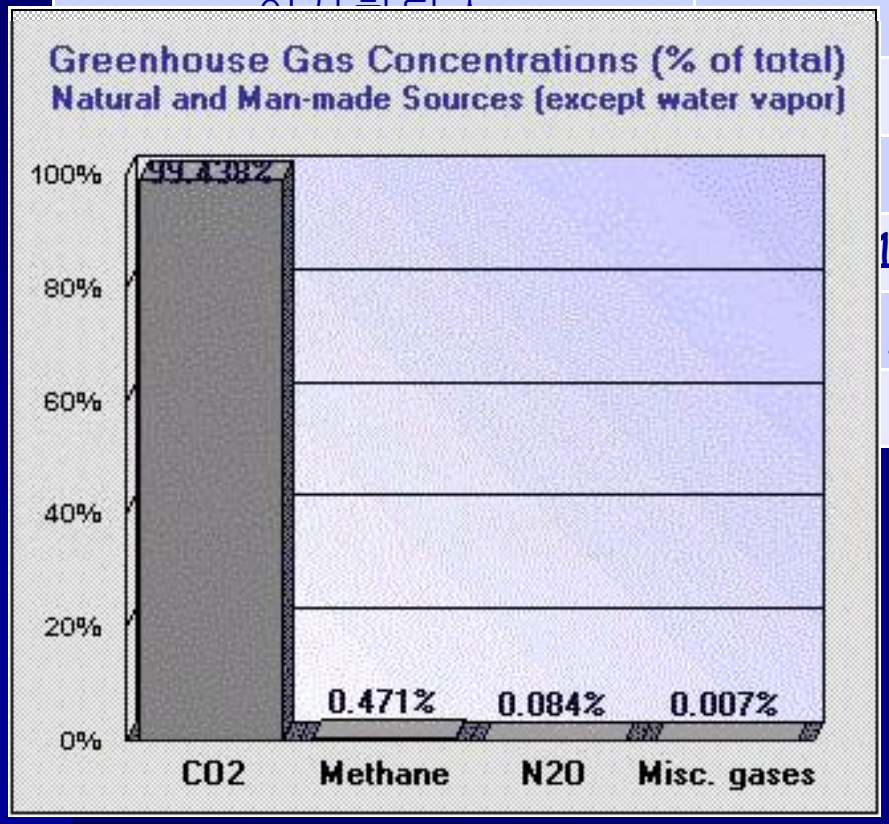
- 2100년까지 지구의 평균 기온이 6도까지 높아질 가능성이 있다.
  - 현재까지 약 0.8도 상승
  - 2도 상승되는 순간 돌아올 수 없는 지점일 가능성 농후

"Six Degrees could change the world" DVD
[National Geographic]

지구온난화지수
Global Warming Potential

온실가스가 지구온난화에 미치는 영향을 표시

온실가스	GWP
	1
	21
	310
	140 ~ 11,700
	,500 ~ 9,200
	23,900



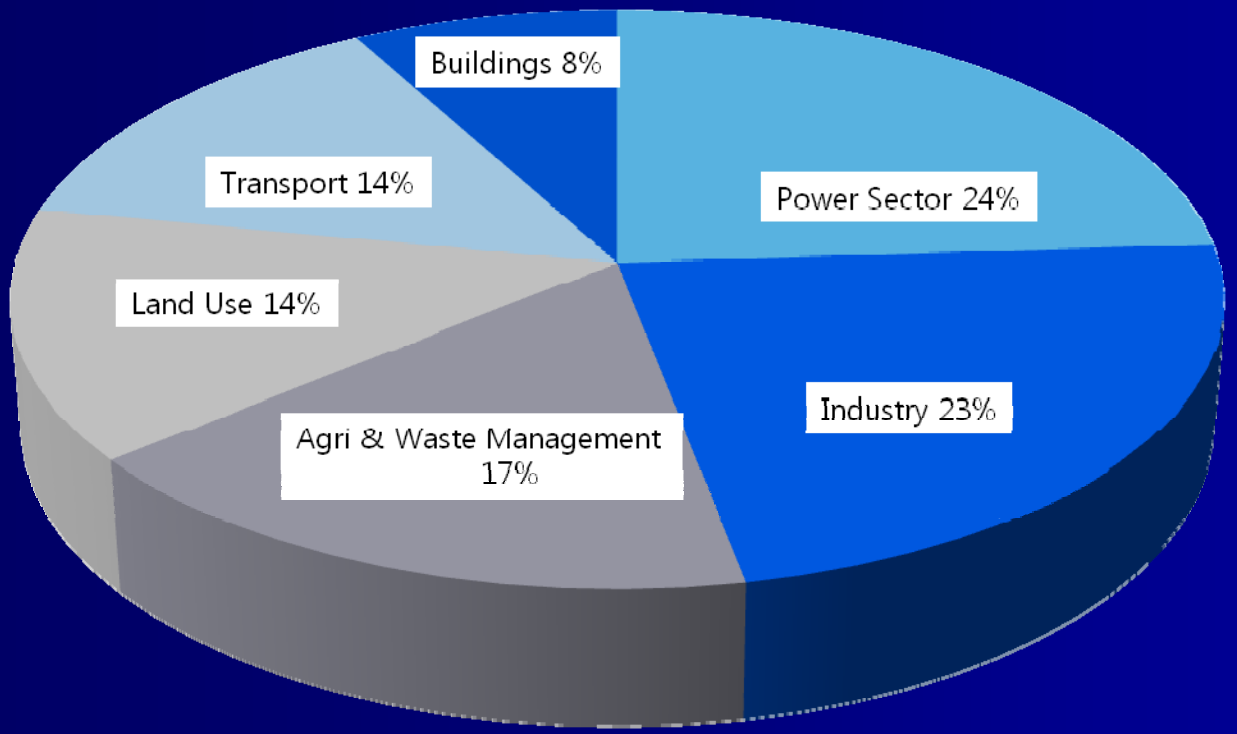
탄소발자국 Carbon Footprint

- 이산화탄소 배출량을 줄이는 것이 급선무
  - Kyoto Protocol: 5.4% reductions below 1990 levels by 2012
  - EU: at least 20% below 1990 levels in 2020
- **Carbon Footprint (CF)**
  - 인간의 활동이나 상품의 생산 소비 과정에서 직간접으로 발생하는 이산화탄소의 총량
  - 예:

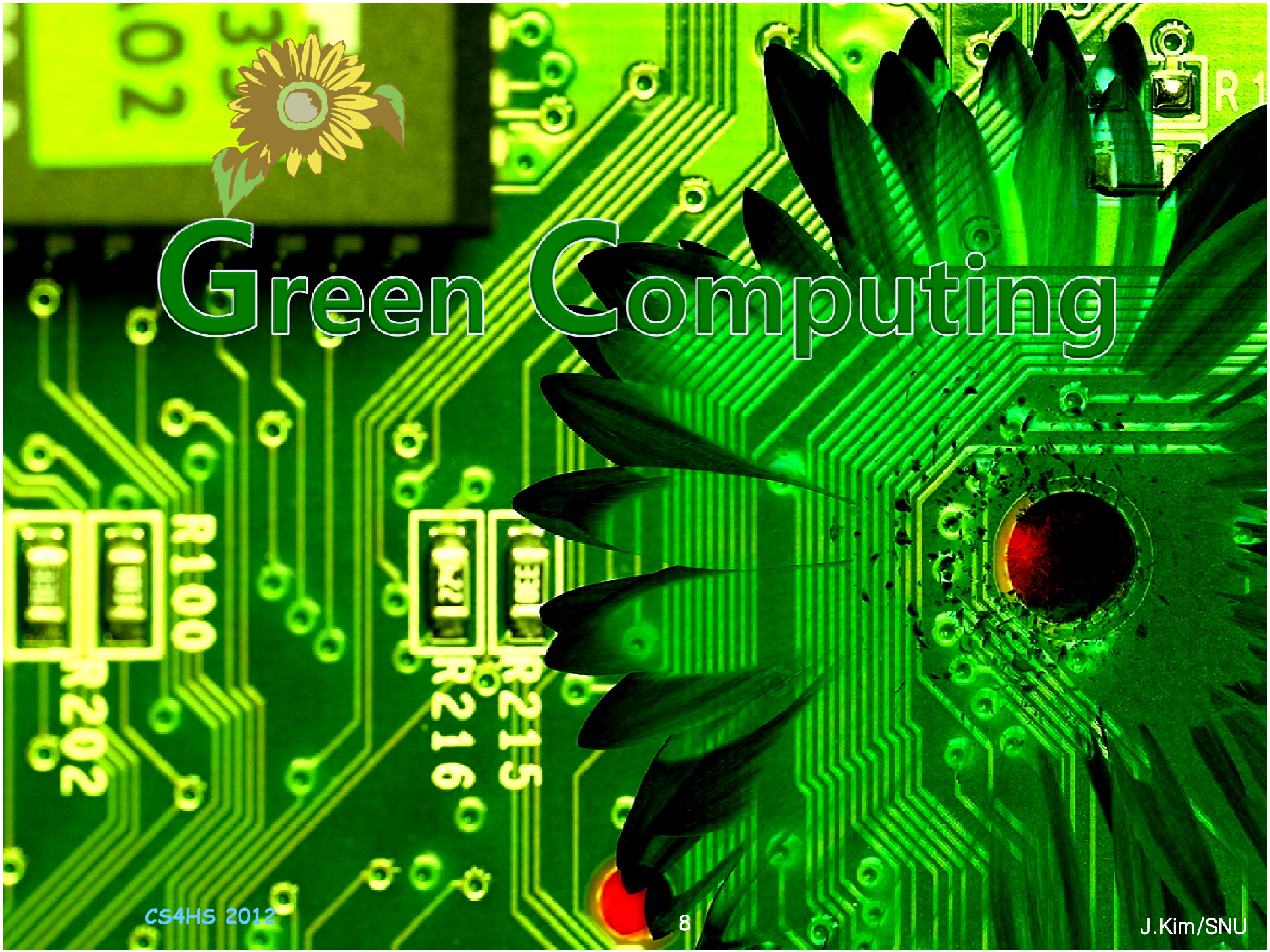
    CF (미국에서 1년에 소모되는 치즈버그)

    CF (미국에서 운행하는 모든 SUV 차량)
  - Carbon Footprint를 명확히 비교하는 것은 상당히 복잡하다.

Carbon Emission Breakdown in 2002



- Power Sector
- Industry
- Agri & Waste Management
- Land Use
- Transport
- Buildings


Green Computing
R100
R202
R215
R216

Green Computing 이란?

- **Environmentally responsible use of computers and related resources**
  - 에너지 효율의 극대화
  - 유해 물질의 사용 절감
  - 폐기물의 재활용 및 생물 분해
  - …

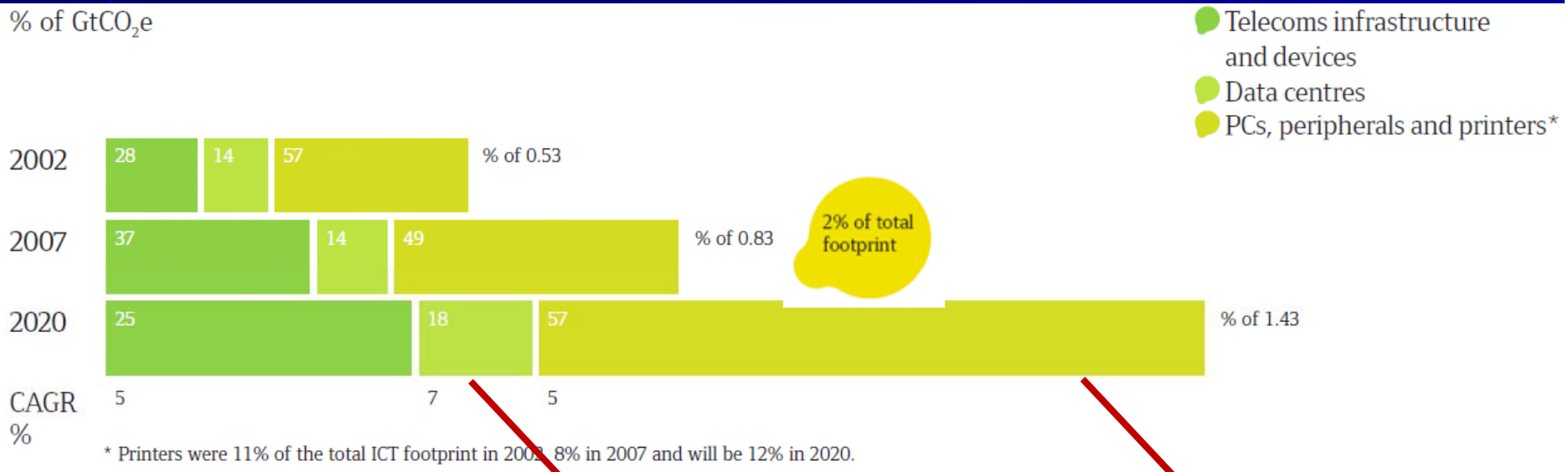
Green ICT

Green by ICT

- ICT == Information Communication Technology

Global ICT Carbon Footprint: ~2%

Roughly equivalent to the Aviation Industry



Data Centers are increasing

PCs are main problems

from 592 Million in 2002
to > Four Billion in 2020

ICT Industry is Already Acting to Reduce Carbon Footprint

[L. Smarr 2009]

Sun's 'portable' Blackbox data center

Company unveils new one-box data center

Sun Microsystems' CEO Jonathan Schwartz showed off the company's new "Project Blackbox" in a Menlo Park, Calif., parking lot Tuesday. Sun says the gear is not only preassembled, but it's tough and arrives ready to run.

Buying Green

updated 10:47 a.m. EST, Wed November 28, 2007

Google pushes 'green' power initiative

Intel Becomes Largest Purchaser of Green Power in the U.S.

Company Tops EPA Green Power Partner List, Vows to Drive for Greater Efficiency While Spurring Growth in Renewable Market

How Microsoft is going green

Biodiesel trucks, solar-powered data centers are just a couple
environmentally friendly track

By John Fontana , Network World , 01/09/2008

IBM Project Big Green

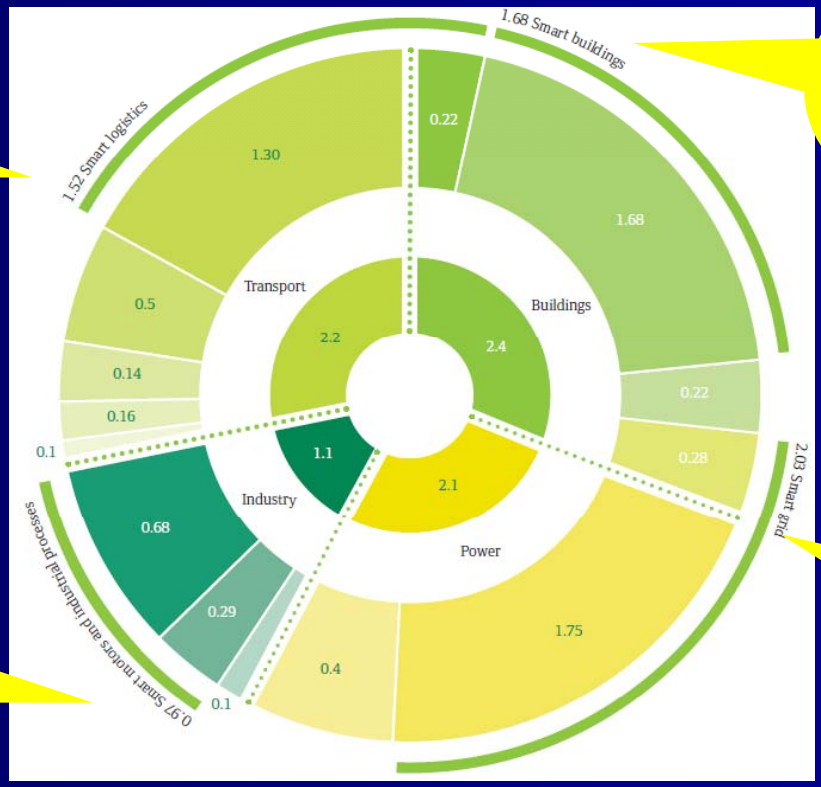
ig Green Banner

Project Big Green is a $1 billion investment to dramatically increase the efficiency of IBM products. New IBM products and services,

Green by ICT

The Smart 2020 Opportunity:
Reducing GHG Emissions by 7.8 $GtCO_2e$ (15%)
(cf. Total ICT 2020 Emissions are 1.43 $GtCO_2e$)

Smart Logistics 1.52 $GtCO_2e$



Smart Buildings 1.68 $GtCO_2e$

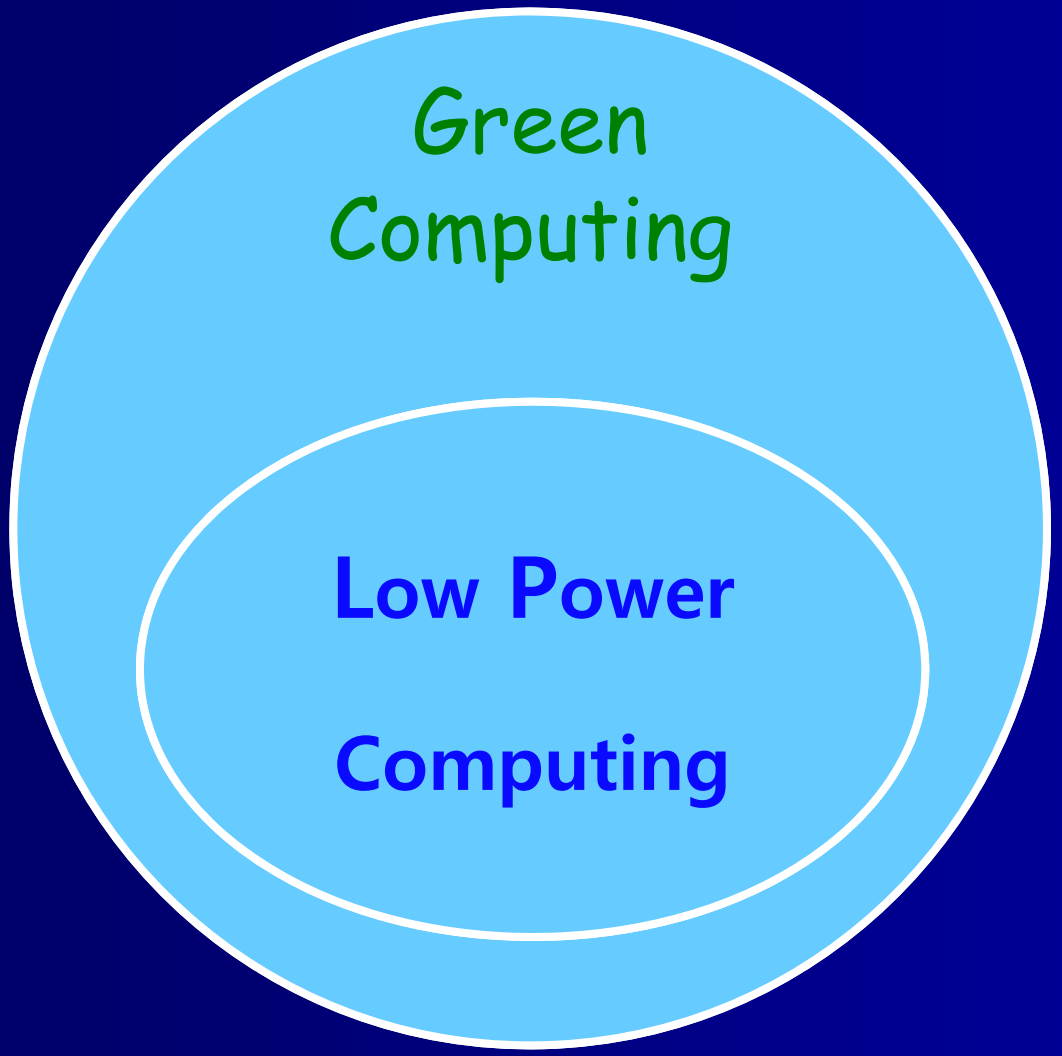
Smart Motors 0.97 $GtCO_2e$

Smart Grid 2.03 $GtCO_2e$

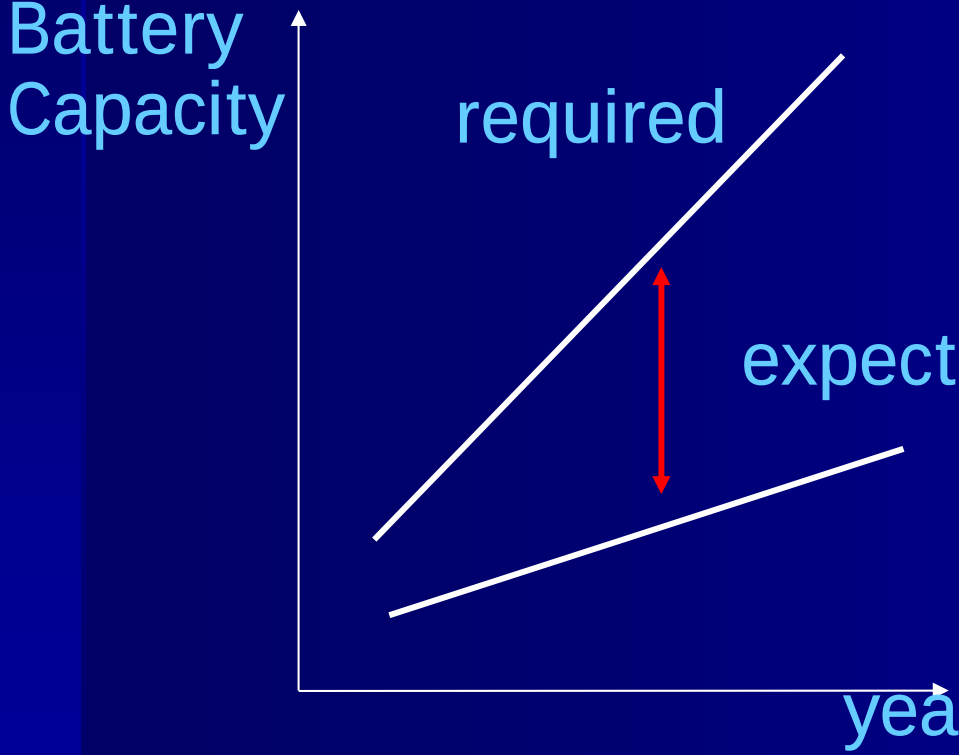
Green by ICT 과정

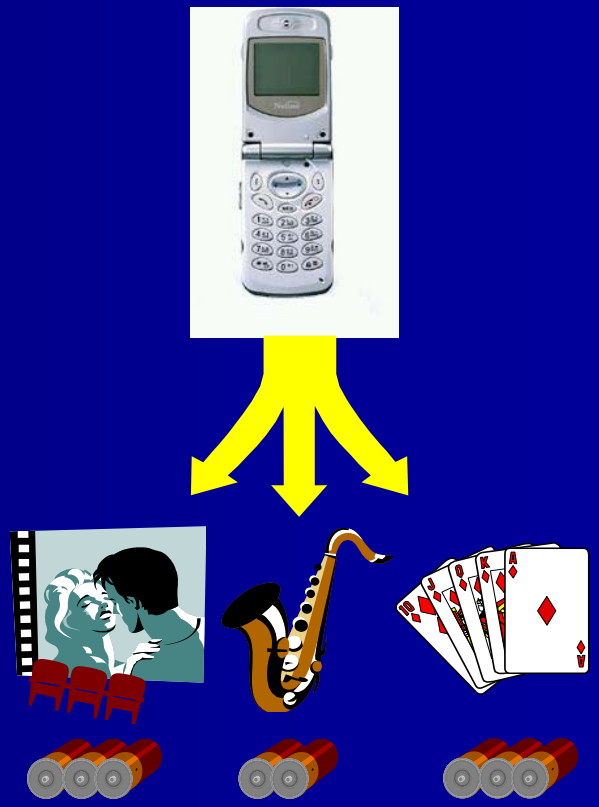
- **Standardize**
  - Develop protocols to enable smart systems to interact
- **Monitor**
  - Make energy and carbon emissions visible
- **Account**
  - Link monitoring to accountability and decision making
- **Rethink**
  - Optimize for energy efficiency and find alternatives to high carbon growth
- **Transform**
  - Implement low carbon infrastructure solutions

Low Power vs. Green Computing

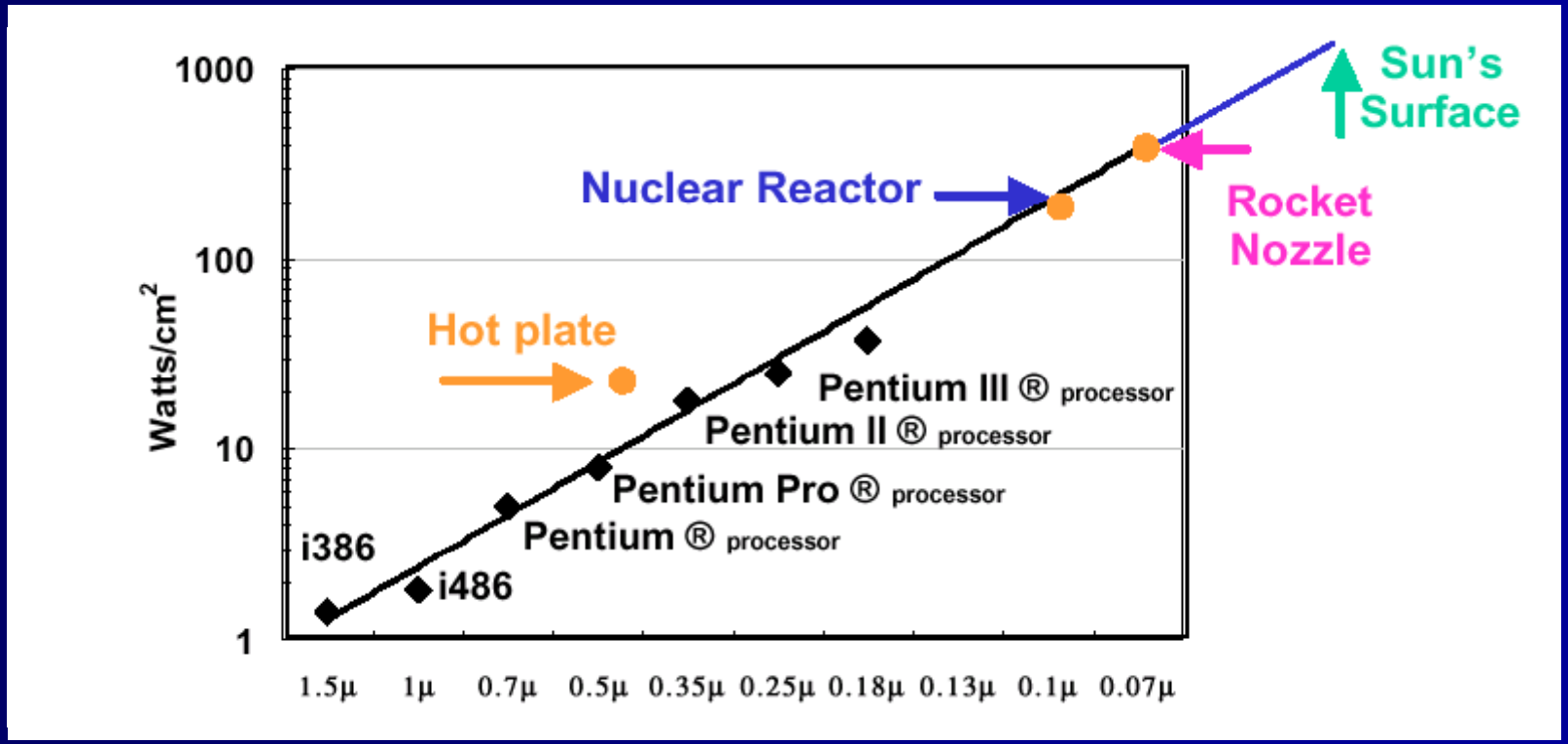


Why Low Power?
- Limited Battery Capacity





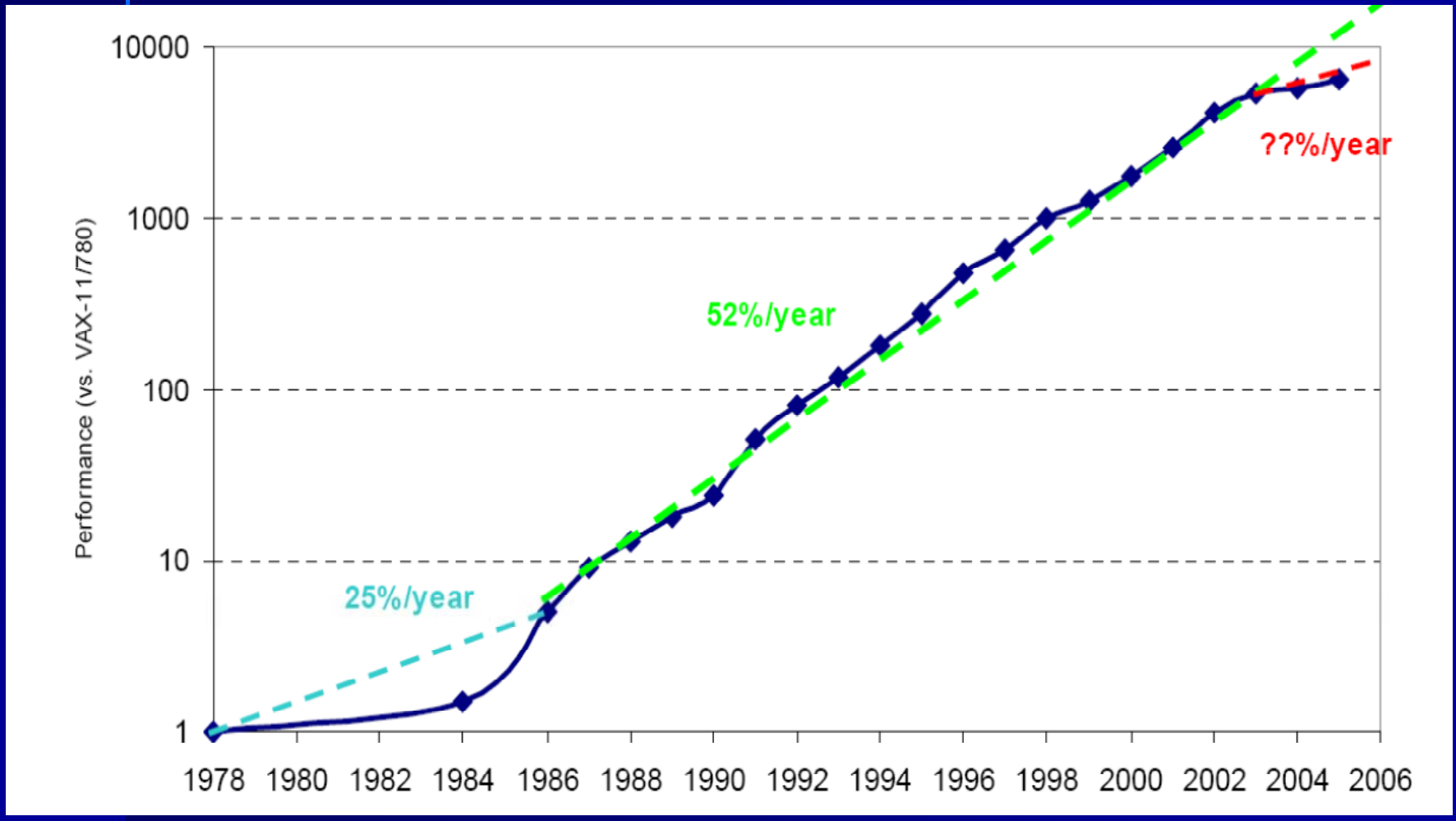
Why Low Power?
- Heat Dissipation



Power density getting worse

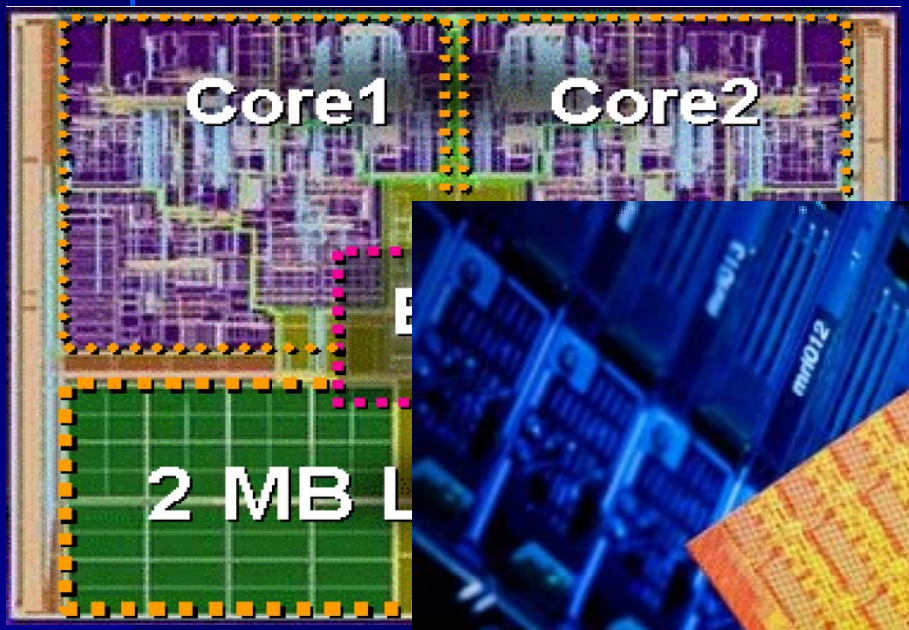
From F. Pollack

Processor Performance Improvement

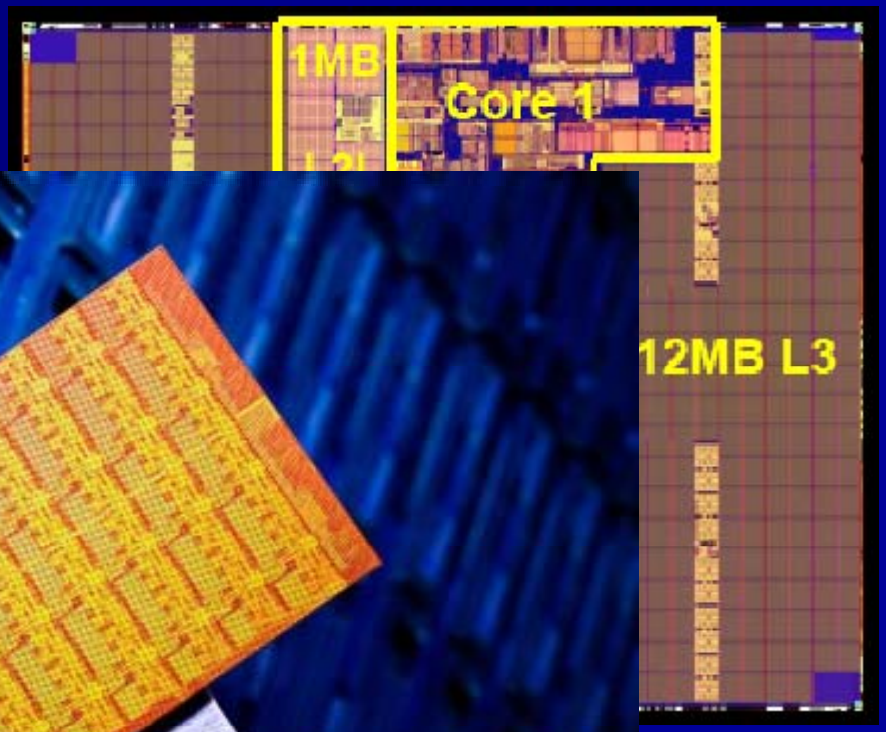


[Hennessy & Patterson 2007]

Intel CPUs



Intel Core

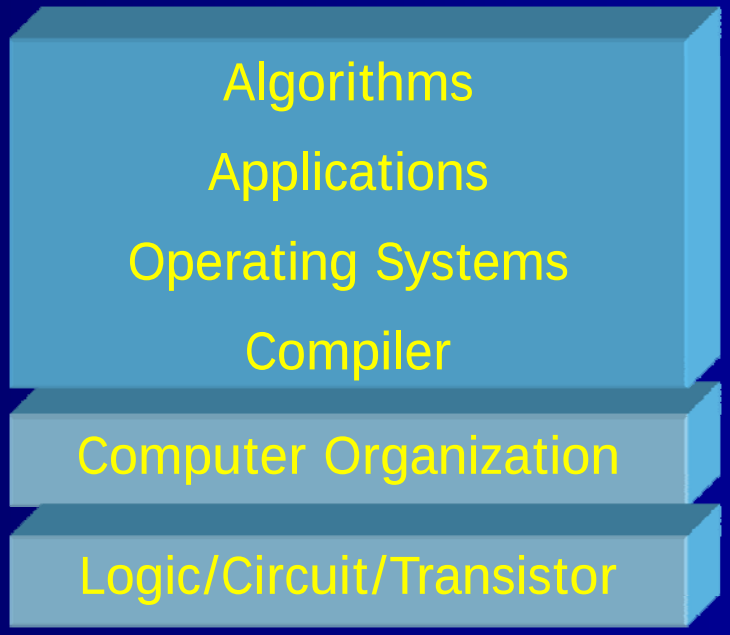


(server)

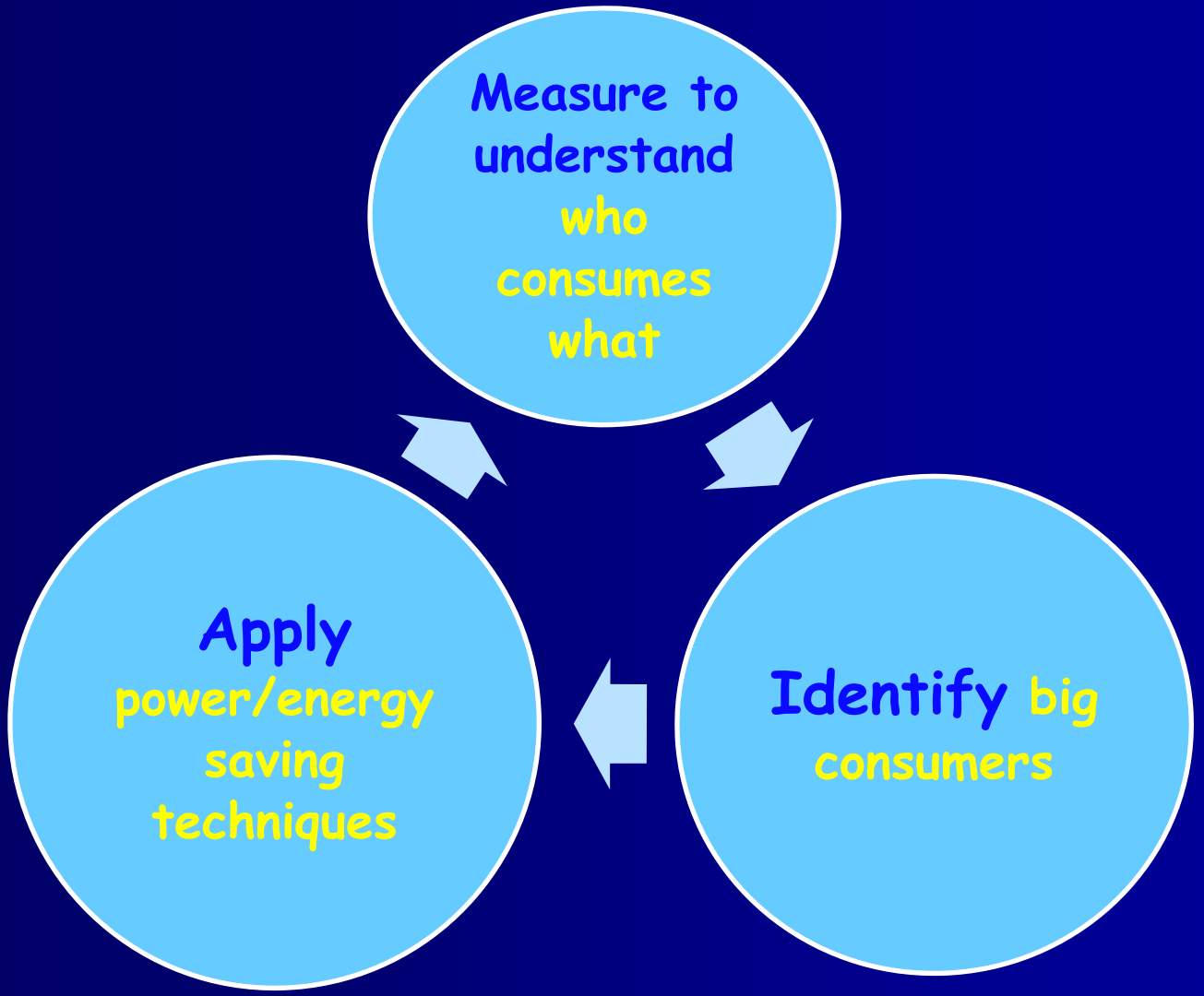
48-core cloud chip

Low Power Computing

- Goal: *Power-Aware Computing*
  - Energy is only consumed if, when and where needed.

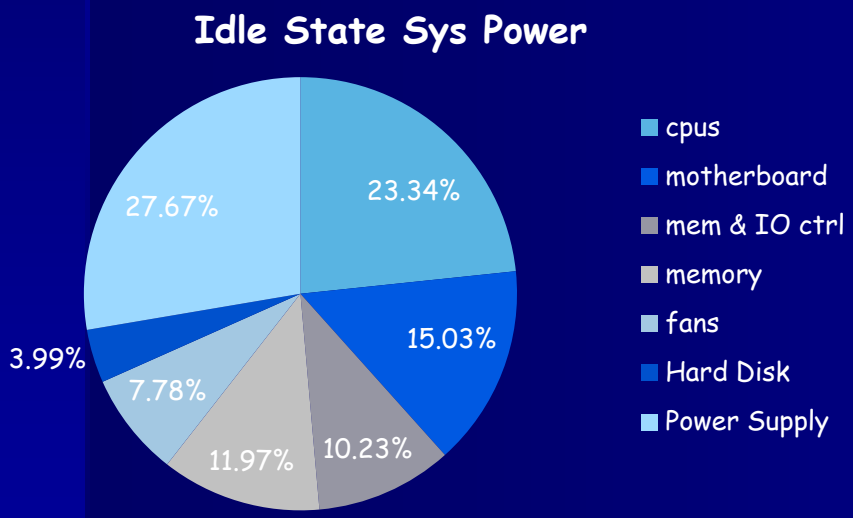


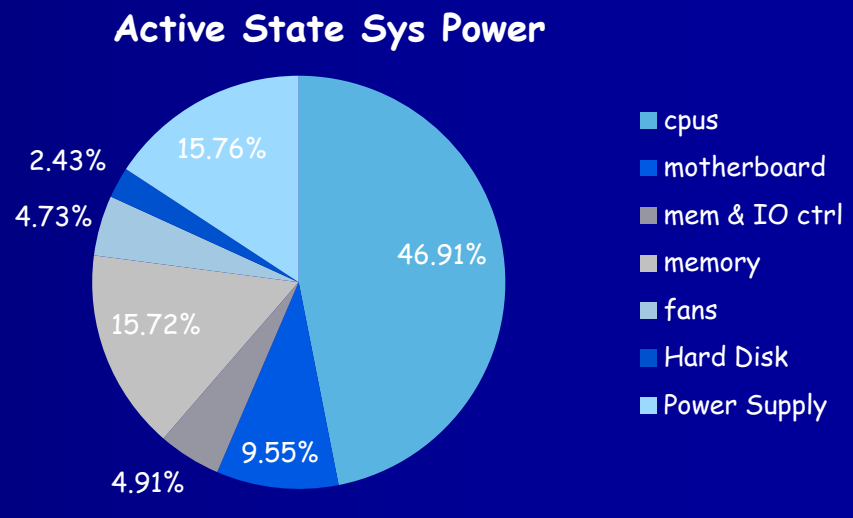
ICT Energy Management



Power consumption of Intel's 2-socket quad core Xeon

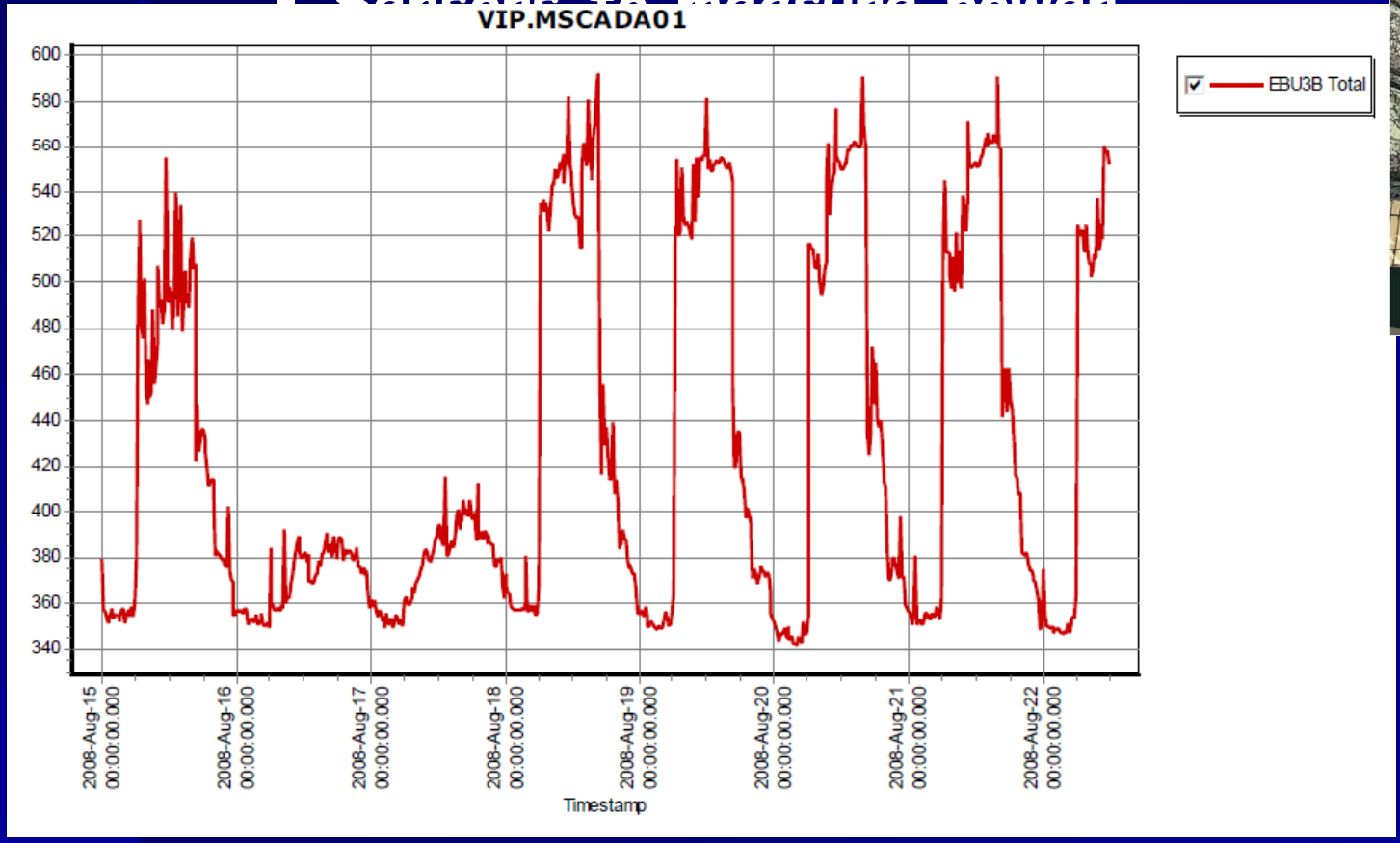
- **Main Contributors:**
  - CPUs
  - Memory
  - Fans & power supply

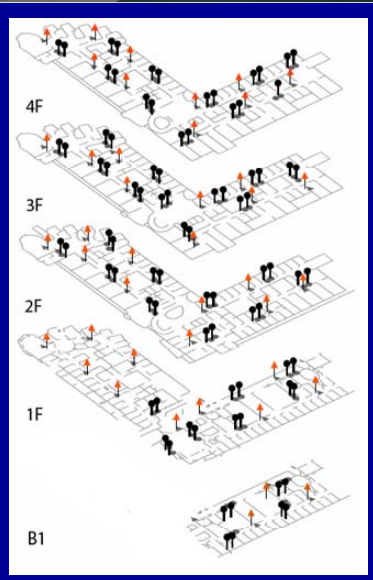




Macro Scale Measurement [Yuvraj 09]

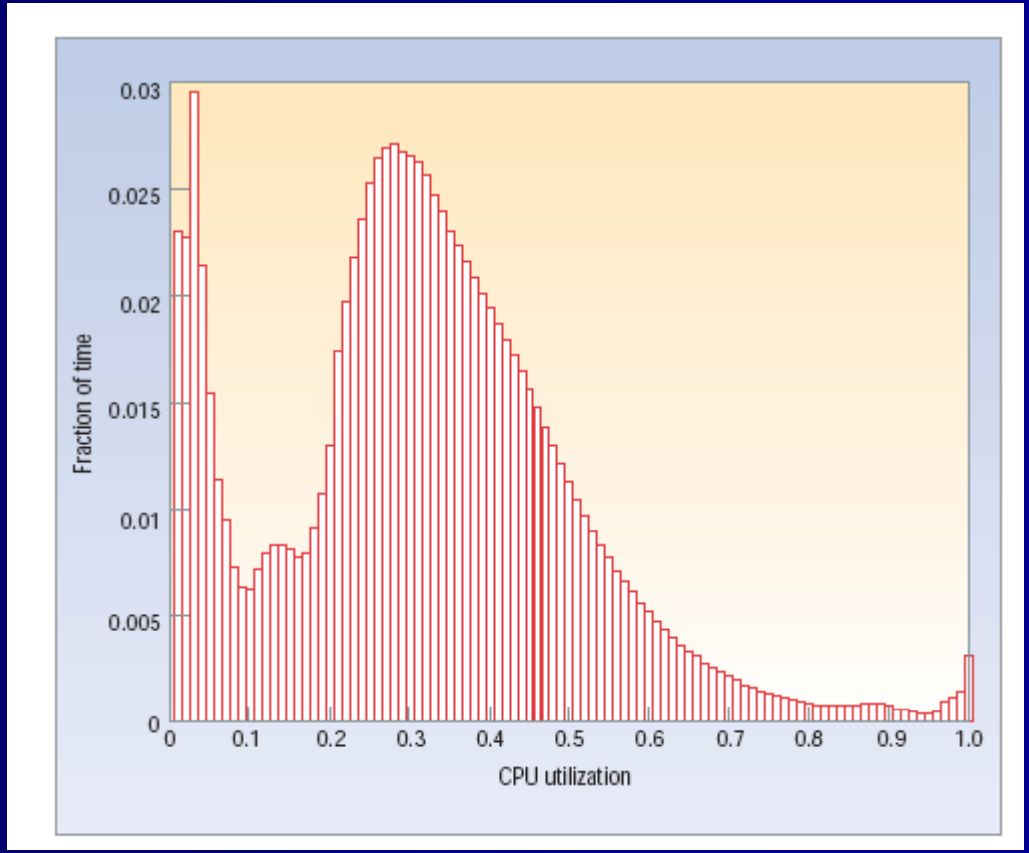
- Instrument the UCSD CSE dept.
  - Sensors to measure power





Google DataCenter

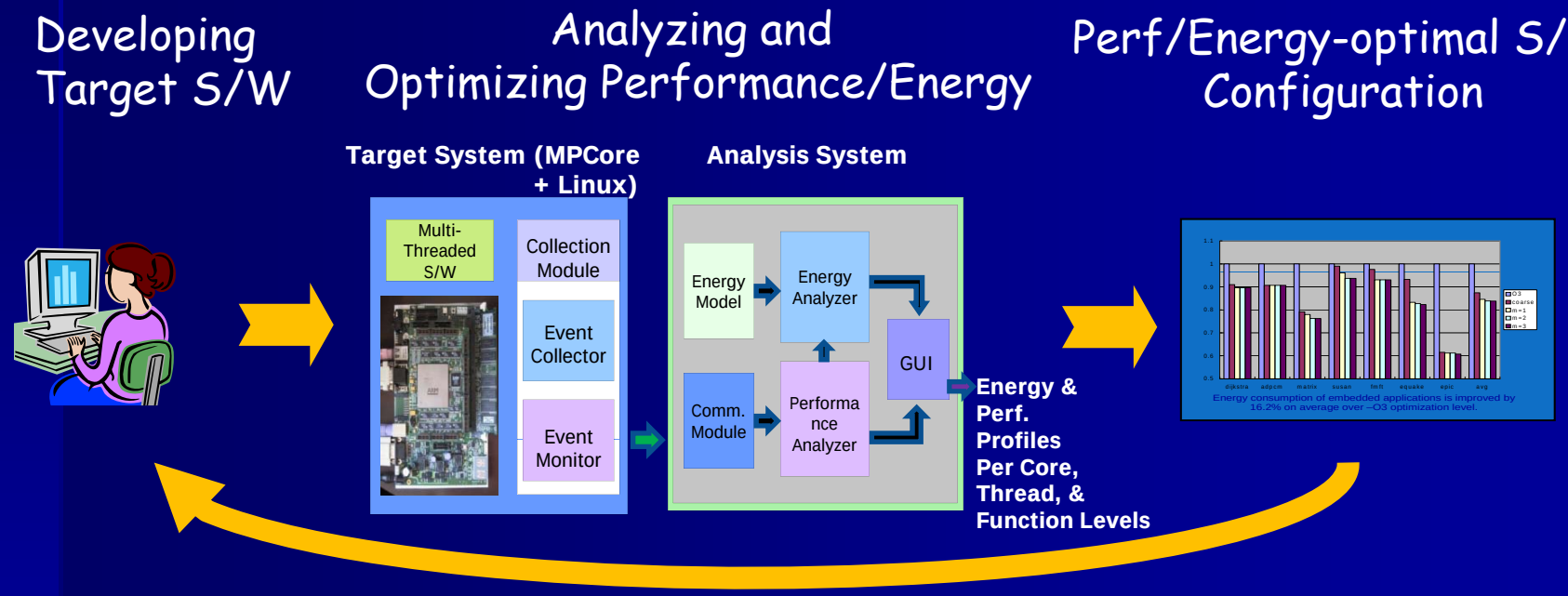
[Barrosso 07]



ePRO-MP

[Choi09]

energy PRofiler and Optimizer for MultiProcessors



- An integrated tool for measuring, analyzing, and optimizing energy, performance, and code size of embedded parallel applications

Successful Low Power Techniques

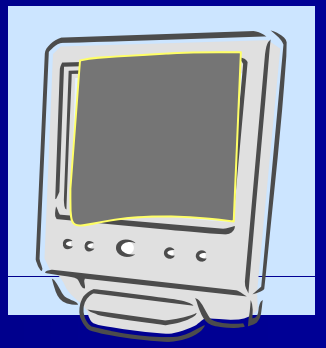
1. Understand workload variations of your target
2. Devise efficient ways to detect them
3. Devise efficient ways to utilize the detected workload variations using available H/W supports

기본적인 저전력 기법 아이디어

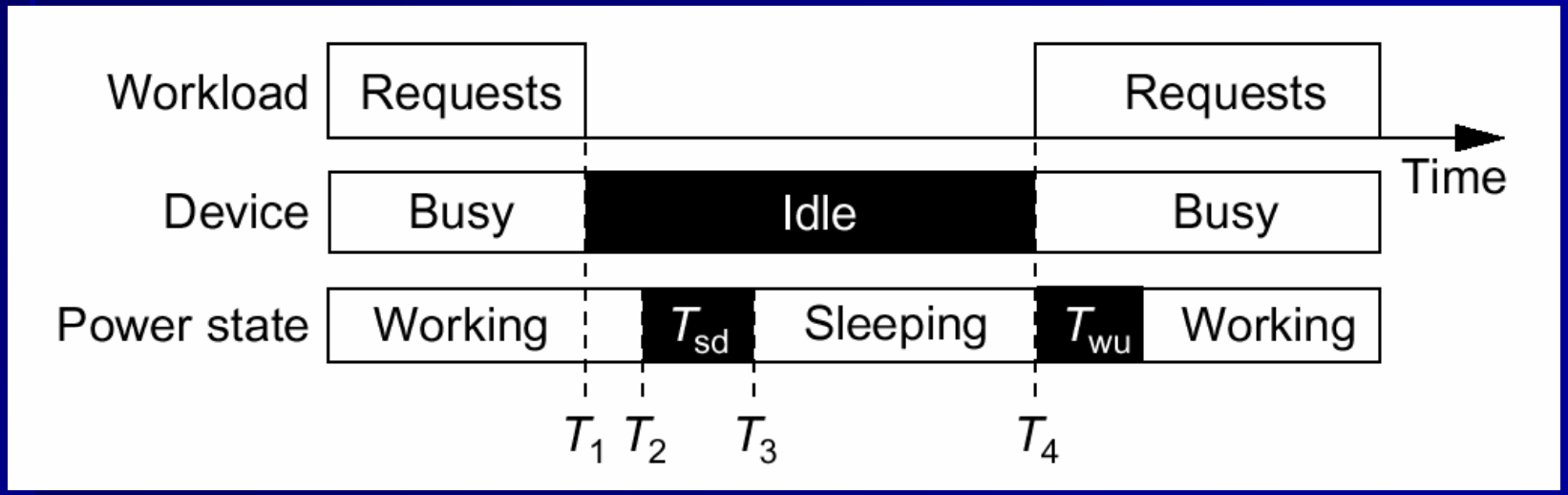
- **Dynamic Power Management (DPM)**
  - 빈방 불끄기
  - 물 새는 수도꼭지 잠그기
- **Dynamic Voltage/Frequency Scaling (DVFS)**
  - 불필요한 힘 사용하지 않기
  - 적정 냉/난방 온도 설정하기

Dynamic Power Management

- System-level power management
  - 다양한 power 상태가 존재하는 시스템에서..
  - Saves power of subsystems (devices)
- Device is:
  - Busy if there are requests
  - Idle otherwise
- Simple DPM examples:
  - Display on/off
  - Hard disk on/off



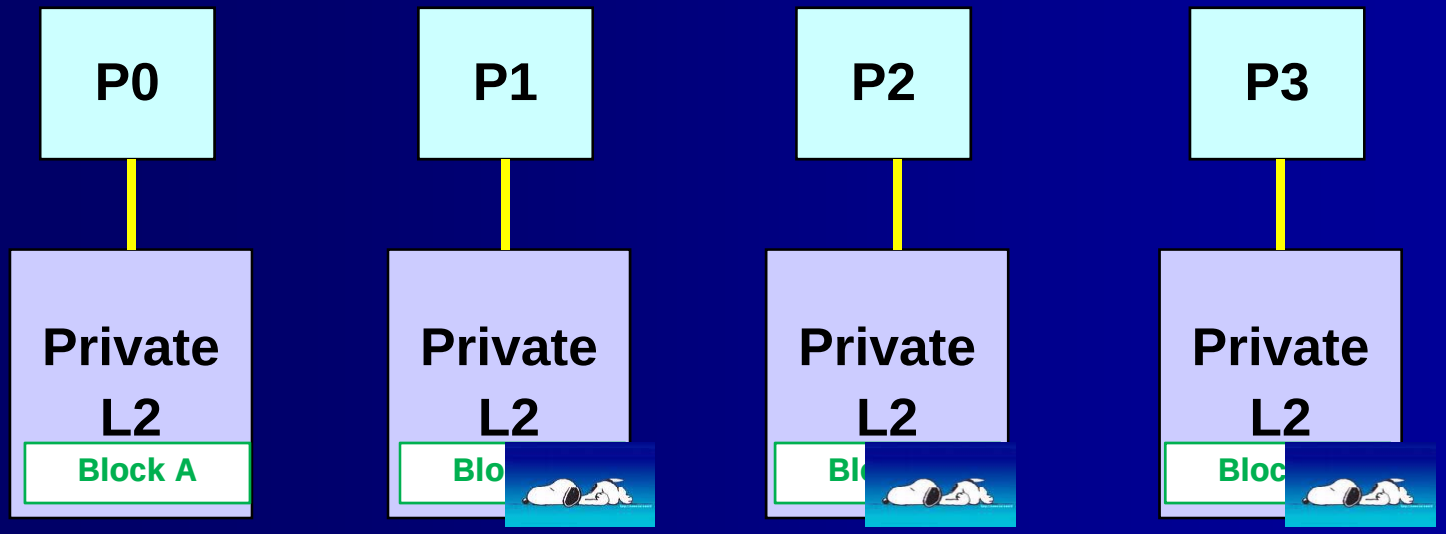
Power State & Transitions



- **Assumption**
  - Only one device & only one stream of requests

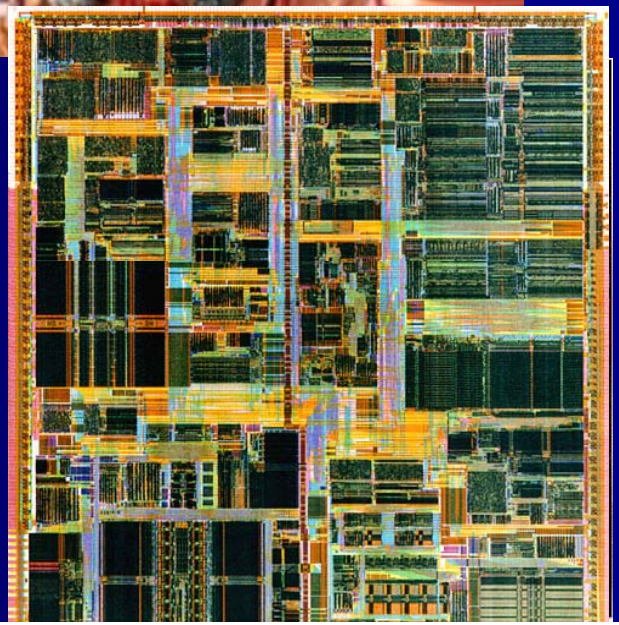
Leakage Management by Turning Off Replications [Kim2009]

- Replicating the shared block in each private L2 cache
  - The cache blocks are replicated in each local private L2 cache to access the cache block faster.
  - The cache capacity decreases.
- Goal: *Reduce the leakage energy consumption* of the private L2 cache by turning off the replicated blocks



Dynamic Voltage Scaling

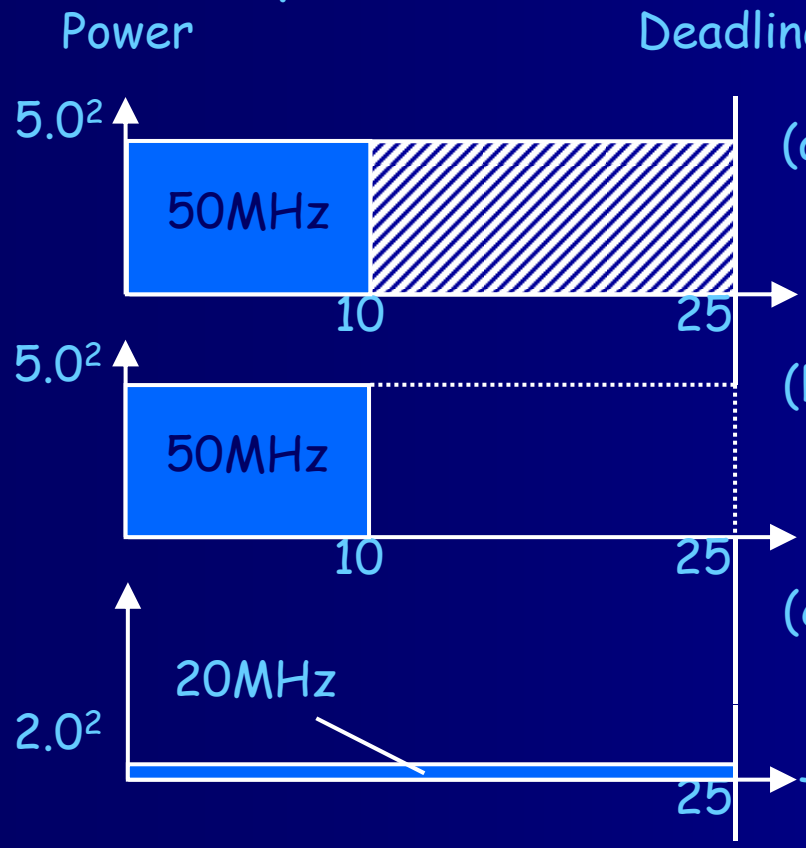
- CPU의 성능을 동적으로 다양하게 조절



Pentium II

Basic Idea of DVS

- $E \propto N_{cycle} \cdot V_{DD}^2$



(a) No power-down
- 12.5×10^8 cycle
- 5.0V
- **31.25J**

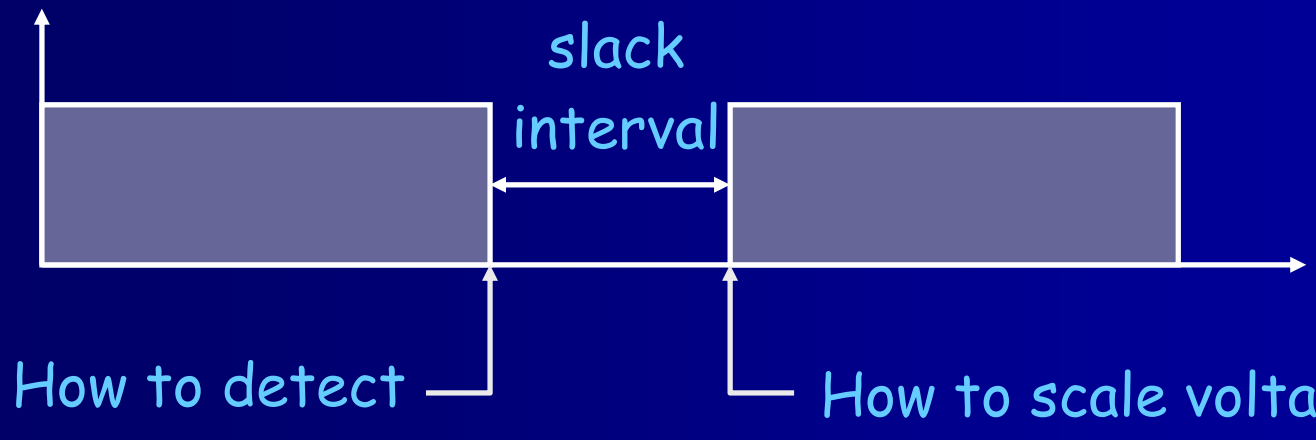
(b) Power-down
- 5×10^8 cycle
- 5.0V
- **12.5J**

(c) Dynamic voltage scaling
- 5×10^8 cycle
- 2.0V
- **2.0J**

→ **Slow and Steady wins the race!**

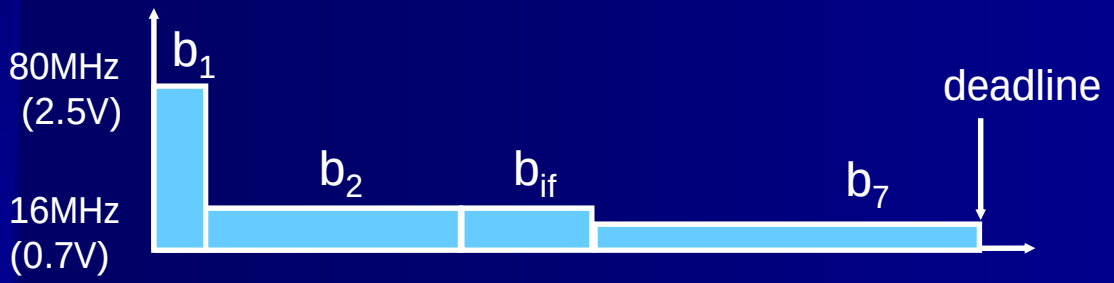
Key Issues for successful DVS

- Efficient Detection of Slack/Idle Intervals
- Efficient Voltage Scaling Policy for Slack Intervals

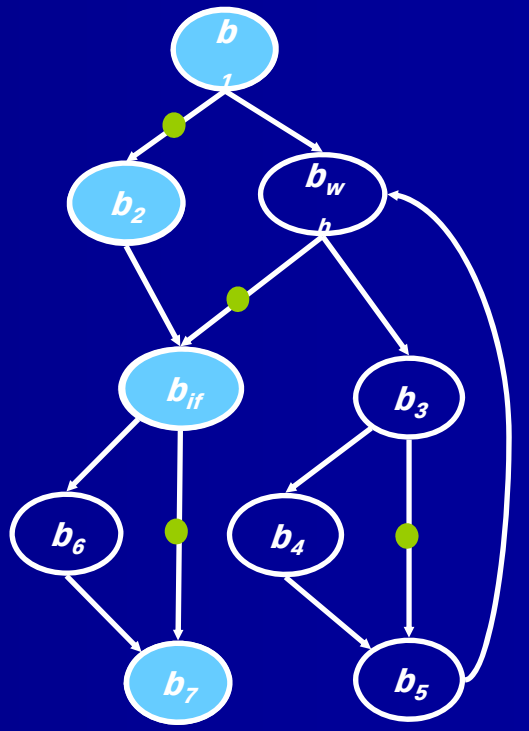


Effect of Intra-Task Scheduling [Shin07]

(a) without the intra-task scheduling

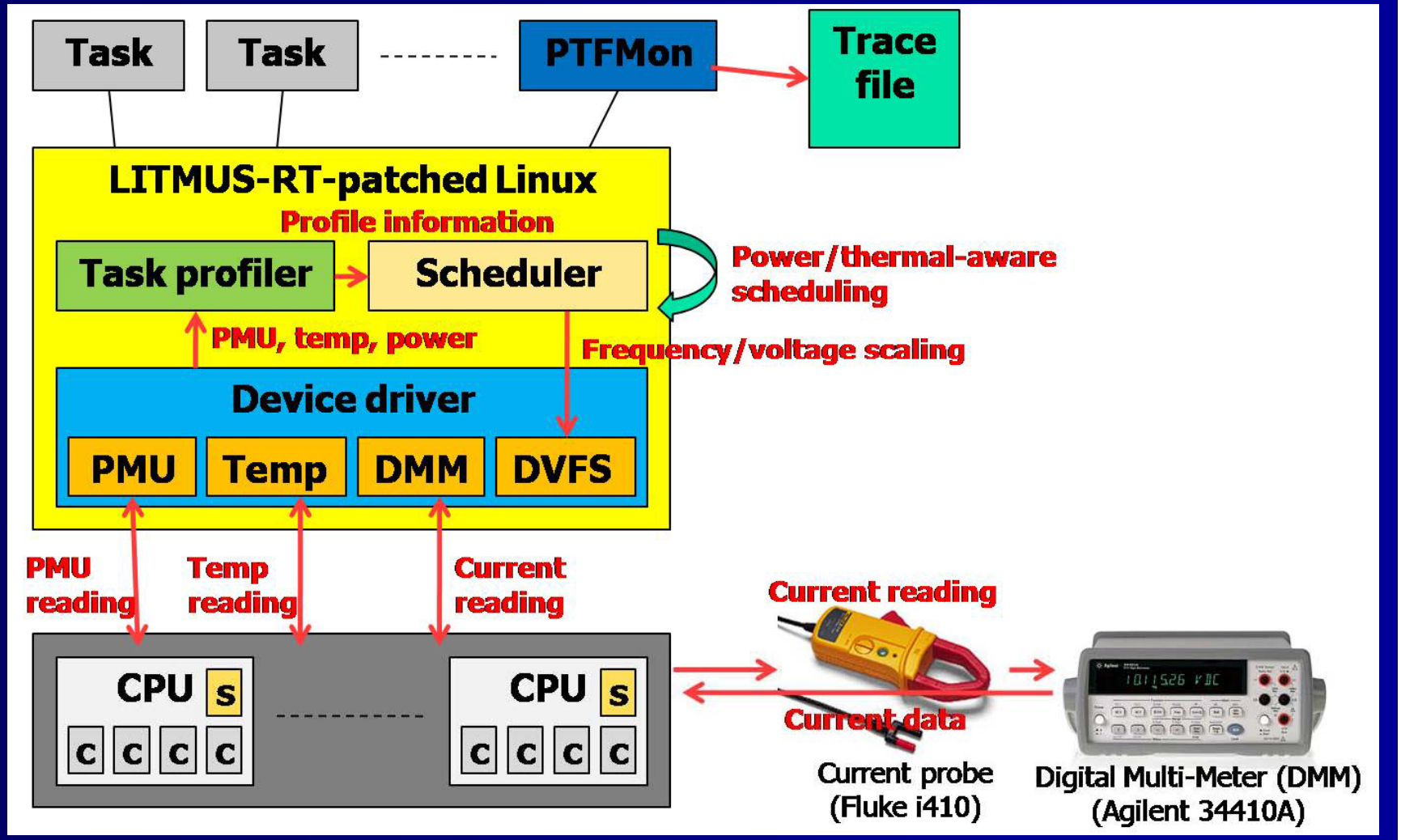


(b) with the intra-task scheduling



$$\frac{\text{Energy Consumption of (b)}}{\text{Energy Consumption of (a)}} = 0.34$$

Power/Thermal-Aware Scheduling

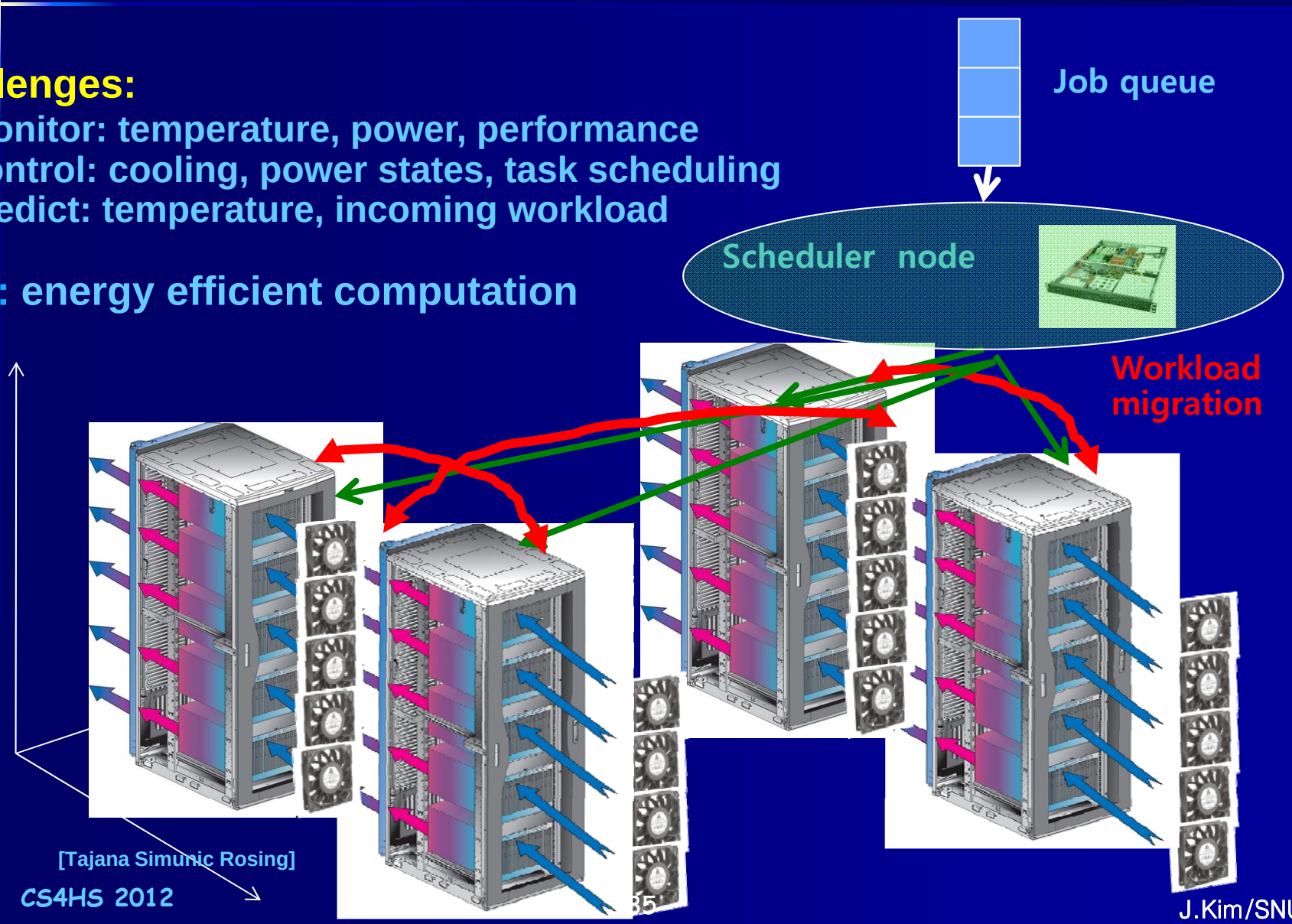


Energy Management in Data Centers

Challenges:

Monitor: temperature, power, performance
Control: cooling, power states, task scheduling
Predict: temperature, incoming workload

Goal: energy efficient computation



Conclusions

- 지구온난화 문제의 해결을 위해서 **Green Computing**을 통한 효율적인 해법이 절실하다.
  - **Green ICT**와 **Green by ICT** 모두 매우 중요하다.
  - **Green ICT**의 주요 접근법에 기반한 창의적인 **Smart Solution**들이 다양한 **sector**들에서 요구된다.

- 효율적인 **Green Computing**을 위해서는 **Low-Power Computing** 분야에서 개발된 다양한 기법들의 적용이 요구된다.
  - 전력/에너지 소모의 분석 및 이해
  - **DPM**
  - **DVS**

- For more info on our group's research, please visit http://davinci.snu.ac.kr

감 사 합 니 다!